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REQUIREMENTS ANALYSIS AND DESIGN FOR IMPLEMENTATION OF A SATELLITE LINK FOR A LOCAL AREA COMPUTER NETWORK

by

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This study will include a technological overview of a VSAT network, requirements analysis for establishing a VSAT link to a LAN, and the functional design of a VSAT link to the NPS AS Department Token-Ring LAN.

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ABSTRACT

The purpose of this thesis is to provide naval computer students with a basic knowledge on Very Small Aperture Terminal (VSAT) satellite technology and to define the hardware and software requirements at the interface between a VSAT and a Local Area Network (LAN). By restricting a computer network to terrestrial links, a vast amount of knowledge is not accessed because either the terrestrial links can't access the information or the information services are only available via satellite. Existing satellite networks could fill this void. It is important for naval officers to understand the VSAT alternative to terrestrial networking. For the purpose of demonstration, a functional design will be presented for the VSAT linkage to an existing Naval Postgraduate School (NPS) Administrative Sciences (AS) Department Token-Ring LAN.

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I. INTRODUCTION

A. PURPOSE

The purpose of this thesis is to provide naval computer students with a basic knowledge on Very Small Aperture Terminal (VSAT) satellite technology and to define the hardware and software requirements at the interface between a VSAT and a Local Area Network (LAN). For the purpose of demonstration, a functional design will be presented for the VSAT linkage to an existing Naval Postgraduate School (NPS) Administrative Sciences (AS) Department Token-Ring LAN.

By restricting a computer network to terrestrial links, a vast amount of knowledge is not accessed because either the terrestrial links can not access the information or the information services are only available via satellite. Existing satellite networks could fill this void. With the ever decreasing costs of VSAT terminals and the economy of scales enjoyed by users of shared hubs, VSAT networking is increasing in popularity and is fast increasing its share in the current satellite communications market. It is important for naval officers to understand the VSAT alternative to terrestrial networking.

This study will include a technological overview of a VSAT network, a requirements analysis for establishing a VSAT link to a LAN, and the functional design of a VSAT link to the NPS AS Dept Token-Ring LAN. In addition, some current and future VSAT applications are discussed which relate to the private sector as well as the Naval Service.

B. SCOPE

This thesis is designed to be used as a tool for understanding VSAT technology and its applications to the NPS AS Department Token-Ring LAN. The technological overview and requirements analysis for establishing a VSAT link will be the thrust of this study. The technological overview will investigate the characteristics of a VSAT link. The requirements analysis will examine a specific LAN and determine the hardware and software requirements necessary to implement the satellite VSAT link.

The functional system design will be included as a subsidiary phase which will incorporate the current AS Dept Token-Ring LAN and generic market hardware and software products. The design phase will include a functional terminal design and an evaluation of terminals available in the market today. Current communications interfaces for LANs and ground station terminals will be discussed for the current AS Department Token-Ring LAN.

II. VSAT: AN OVERVIEW OF AN ALTERNATIVE MEDIUM

A. TECHNOLOGICAL OVERVIEW

1. Satellite Introduction

a. Basic Satellite Technology

A communication satellite permits two or more stations on the ground to send messages to each other over great distances using radio waves. The communications satellites pertinent to this study are geostationary. That is, they are in a geostationary orbit that revolves around the earth in the plane of the equator every 24 hours. They maintain precise synchronization with the rotation of the earth. Thus, three geostationary satellites positioned 120 degrees longitude apart can provide entire global coverage less the polar regions.

A key aspect of a geostationary satellite is its ability to provide coverage of an entire hemisphere at one time. This is accomplished by each satellite having a specially designed communication beam. Any area that this "footprint" or area of coverage includes will be able to receive the same transmission. Thus, the satellite's footprint of its beam can transmit to large contiguous land masses or small offshore locations, as seen in Figure 1. Typical satellite systems are designed to last ten years due to inability to service geostationary orbits and replenish consumables.

In connecting two distant users, a VSAT channel allowing simultaneous two way interactive communication (full-duplex mode) needs to employ earth stations at each user site. The availability of small, low-cost earth stations which take advantage of more sophisticated satellites has allowed the smallest potential users to apply satellite bypass networks to achieve economies of scale and save time and money. The idea of every business or home having a satellite dish on the roof is now possible.

b. Implementing Satellite Systems

The actual implementation of a satellite system can be broken into two segments: space segment and ground segment. The space segment involves satellite placement in orbit by a contractor and a launch agency. Once in place, this repeater is fixed in space and can link many points on earth. This segment will be accomplished by the communications company and users may in turn purchase or rent satellite capacity directly without becoming involved in the space segment. The ground segment operates to access the satellite repeater from these points in order to serve the communication needs of the users. These points are referred to as "earth stations" and can vary in sophistication and size. The integration of these earth stations and repeaters make up the satellite network.

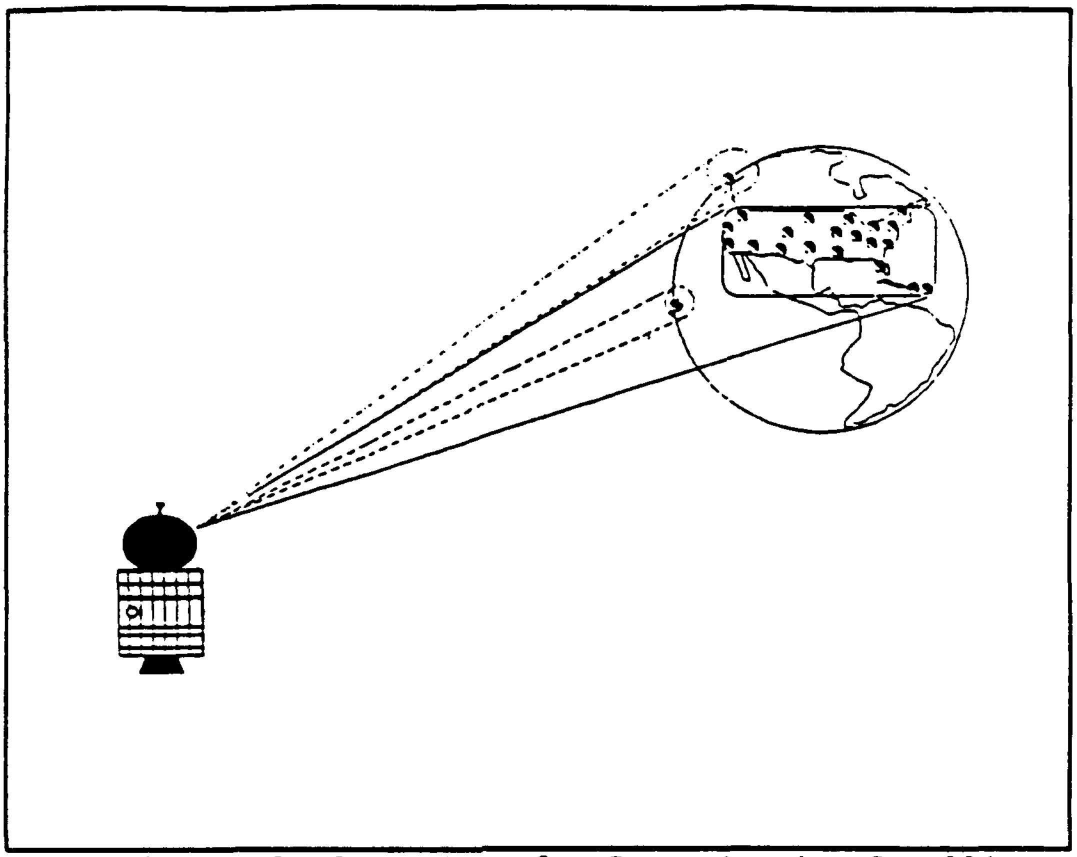


Figure 1 Example footprint of a Communication Satellite.

c. Satellite Transmission

Electromagnetic waves are used in satellite communications to carry information between ground and space. Frequency is measured in Hertz, which is the rate of reversal of polarity in cycles per second. A set range of frequencies is called a frequency band. Satellites use the radio frequency band (RF). The most useful RF frequencies lie in the microwave bands, approximately between 330 Mhz and 300,000 MHz. Today's most popular satellite bands lie between 1 GHz (1000 MHz) and 30 GHz.

Typical satellite bands are divided into two sections: an uplink for the ground segment; and a downlink for the space segment. An uplink frequency band is usually slightly higher than the downlink frequency band to take advantage of the fact that its easier to generate more transmitting power at an earth station than onboard a satellite, where power and weight are limited. In addition, as frequency increases, conversion efficiency from AC power to RF power decreases. Usually, an earth station's power amplifier is greater than its satellite's by a factor of 10 to 100.

When a popular frequency band is used by terrestrial microwave links, care must be taken to use frequency coordination when satellite networks utilize the same frequency bands. Frequency bands must be "shared" to ensure users will avoid harmful RFI (Radio Frequency Interference). This is true for most of the microwave satellite bands. Only a few bands are not shared and they lie higher in the spectrum. Currently, parts of the Ka and Ku bands (above 10 GHz) are not shared with terrestrial microwave and only satellite use is permitted.

d. Satellite Networks

A single integrated satellite network can consist of expensive major earth stations for large demands and smaller inexpensive earth stations for more remote and less demanding traffic loads. Connection with the terrestrial networks can be accomplished through major earth stations that access the public switched network (telephone system) or international gateways for international communication. For large communications loads, major users can best be served by operating separate earth stations for their large volume of traffic (telephone calls, video or data transmissions etc.). Smaller stations, however, are inexpensive enough to justify their use at low traffic loads and less demanding communications transmissions. The term "VSAT" means very small aperture terminal and is used to describe a compact and inexpensive earth station. Refer to Figure 2 for an example of an integrated satellite network using VSATs, Hubs and Gateways to the Terrestrial Network.

2. VSAT Technology

VSATs use small antennas (typically 6 feet or less) and microprocessor controllers to bring the power of satellite communications to data networks. A VSAT system consists of the data link between the host computer and a MES (Master Earth Station) that uses a satellite to relay data to and from the VSAT. In a satellite network, the user can view the VSAT as a toll switch in the sky, eliminating local loops, intra-LATA tolls and even PBXs in some cases. The key to effective VSAT is its interactive nature, allowing two-way

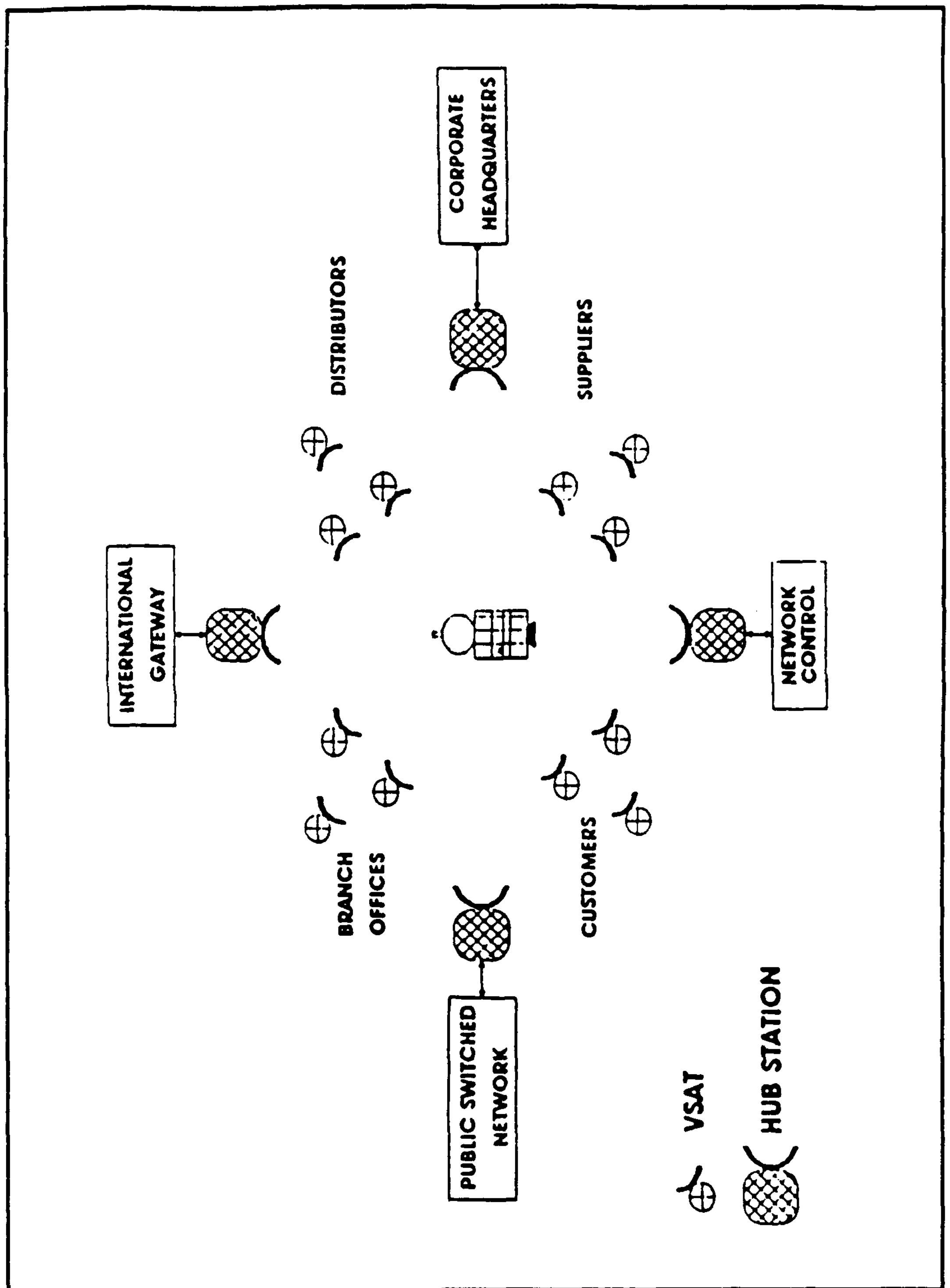


Figure 2 Example of an Integrated Satellite Network Using VSATs, Hubs, and Gateways [Ref. 4:p. 341].

communications with remote stations very similar to the terrestrial telephone system.

The hub or shared hub, is the heart of a VSAT network and is a sophisticated earth station that routes as well as controls the flow of information through the system. This shared hub operates a network management system that accesses the satellite repeater and manages the communications between VSATs and the MES.

With the use of higher band frequencies, crowded frequency bands in large traffic areas can now be accessed. Frequency coordination is no longer necessary with Ku band transmissions. Ku band can utilize higher downlink power, thus smaller ground station dishes, since the frequency band isn't shared. As a result, Ku band is very attractive for highly developed areas, where only small dishes can be mounted in confined areas.

3. Broadcast/Receive Only VSAT

The most common application for satellites is data broadcasting. Point to multipoint connectivity is used to deliver information to various receiving stations. Data is transmitted in fixed blocks, called packets with each packet addressed to certain receivers with some coded so that only authorized users can gain access to the information. A central hub station uplinks an almost continuous stream of packets to the satellite. The data broadcast reaches the receive-only terminals which lie in the same satellite footprint. Since each packet is independently addressed and self-contained, it can be routed in any direction over the satellite and eventually through a terrestrial packet switched network.

4. **Interactive VSAT**

While data broadcast has a variety of uses, most data communication requires that the remote terminals be able to respond back to the central site and share information between one another. An interactive VSAT network has two-way communications with no requirement for terrestrial facilities.

Multipoint to point satellite networks complement the broadcast approach by allowing remote stations to send information back to the central station. It provides two-way communication because the remotes receive the broadcast from the central station and can transmit back over the same satellite. Many commercial applications can use this connectivity where subscriber response is necessary.

Satellites have sufficient bandwidth to carry several TV channels plus an array of voice and data traffic. VSATs operating with Ku band can carry multiple services, including CATV and video teleconferencing. With this new generation of earth station, flexibility of satellite communications is improved with new services.

5. Points to be Considered for VSAT Usage

In examining the effectiveness of a VSAT network, four general features need to be considered: Connectivity, Flexibility, Reliability, and Quality. Connectivity and flexibility can be easily explained and quantified. The remaining two are more difficult, but could ultimately be the deciding factors in using satellite transmission.

a. Connectivity

Connectivity is the manner in which points on earth are linked between each other. There are three forms of connectivity: point-to point, point-to-multipoint, and multipoint-to-point. Optimum usage of satellite networks is achieved whenever a multipoint connectivity system is required.

With a point-to-multipoint system, satellite transmission takes advantage of economy of scale. Satellite broadcasting is accomplished using one transmitting earth station hub and many receive-only earth stations. The cost of the hub can be shared and, with higher transmitting power, Receive Only antennas have smaller aperture diameters, which reduces ground terminal costs.

b. Flexibility

A satellite based network is inherently flexible in implementation, expansion, simplification of routing, and introduction of new services.

Implementation of the ground segment of a satellite system is straightforward and involves a minimum number of physical installations. Assuming the space segment is in place, a planner need only consider the sites requiring service. Typical time to implement satellite networks and add stations has been reduced from one to two years down to one to two months [Ref. 1:p. 47].

Satellite systems can be expanded to include additional sites without affecting existing stations. All that is necessary is to purchase the equipment, prepare the site and install the stations. With programmable digital technology, existing sites can be reprogrammed for additional stations.

A complicated and redundant method of circuit switching for communications rerouting is eliminated by using a satellite network. Time delays of many weeks and months involved in making wiring changes are not needed. "In a modern satellite network, only the end connections are involved, because the satellite itself provides all of the intermediate routing" [Ref. 1:p. 48].

A satellite network can be expanded by adding many new services. Satellite repeaters have sufficient bandwidth to carry several TV channels along with an array of voice and data traffic. In addition, two-way interactive video teleconferencing services is provided by the current generation of VSAT, particularly the VSAT using Ku band.

c. Reliability

A disadvantage of satellite transmission is propagation delay which adversely affects interactive processing and can introduce unacceptable delays in broadcasting services. In most systems, this satellite message delay can be handled using a delay compensation unit, supplied by the carrier. But additional delays can also be incurred going through various ground-based switching equipment. The total number of delays incurred for each link needs to be considered by the user.

On the other hand, because satellites use one repeater hop or two in the case of international services, they tend to be very reliable. When engineered properly, the link can be up and usable for well in excess of 99% of the time [Ref. 1:p. 49]. Equipment failures on satellite links do occur, but 100% backup for all critical systems is maintained to avoid catastrophic failure. In addition, if failure does occur, ground facilities are under the control of one organization and can be quickly troubleshooted for maintenance.

d. Quality

Quality can be measured using three different approaches: signal reproduction, voice quality and echo, and data communications and protocols.

As for bit error rates, satellites are almost perfect. Satellite systems radiate enough power in their footprints to be received by ground antennas with 3-32 foot diameters and experience mostly receiver noise, which can be easily compensated for with power. Satellite transmissions handle virtually all long distance video programming with the perception of studio quality.

However, the quality of voice transmission is degraded with satellite delay and has not met with much satisfaction with the public sector. Terrestrial systems do not suffer as much from delay and are thus more acceptable given equal factors. Although, as technology improves and the methods for delay compensation and echo canceling develop, "...there is strong evidence that an advanced digital voice communication link with modern echo cancellation will be rated higher in quality by telephone subscribers than a traditional analog voice link on a long distance terrestrial network" [Ref. 1:p. 53].

If data is prepared properly for transmission, satellites are beneficial in the area of data communication. The factor of success is employing the correct protocols and coding schemes. Older protocols like IBM's Bisync transmitted short words, and required acknowledgement for good reception. Unfortunately, with satellites the delay between transmissions would be intolerable. With the advent of the Delay Compensation Unit (DCU) and standard protocols that don't utilize repeated acknowledgements, such as IBM's SDLC or ISO HDLC, long segments of blocks are transmitted before any acknowledgement, and all retransmission requests are in blocks. As a result, "such modern protocols make satellite links essentially as efficient as the best quality terrestrial links for the transmission of high speed data" [Ref. 1:p. 54].

B. VSAT APPLICATIONS

1. Proper VSAT Applications

The correct use of VSAT network systems can provide an economical solution to many communications needs, but one system will not solve all problems. A user must examine his communications requirements and the minimum resources for success.

> "System design of small earth station networks must be clearly focused on the class of applications to be addressed, adding no unnecessary capabilities that drive up cost per site" [Ref. 2:p. 35].

Large VSAT networks can exist only if the cost per site is kept low enough. This cost is derived from the cost of installing and maintaining the earth station, satellite usage cost, and network costs.

VSAT applications are divided into two classes: (1) broadcast or receive-only, and (2) transaction-oriented or interactive. Each class offers unique services for individual communications needs.

Broadcast networks are ideal for information providers, whether in the form of updated databases dumping or historical database transfers.

For companies that require updated information from a centralized database periodically, a broadcast service that delivers a large database to each station can be very effective. With the decreasing cost of computer storage, each station can maintain their own database and make their own queries locally without querying the central database. As an example, E.F. Hutton currently reduced their communication costs by switching to a broadcast service to deliver their centralized database to their 400 branch offices [Ref.2:p.25].

For companies that require data broadcast but still need infrequent query access to the centralized database, a data broadcast with dial-up service can be economical. With the broadcast service, stations will receive updated databases for storage, and will be able to provide a real-time display. In addition, dial-up service will be invoked by the user when requesting information from the central site. "The software then accesses the central host through dial-up to an 800 number or a local access point on a public packet network. The infrequent use of this reverse path makes this the most economical approach" [Ref. 2:p. 29].

For online applications with hundreds or thousands of user stations, earth stations with transmitters are often justified. The nature of the transaction can lead to significant cost savings.

> "The use of a satellite-based transaction network operated as a common carrier can provide cost savings not possible in leased line solutions by taking advantage of the different capacities required in each direction." [Ref.2:p. 29].

The typical inquiry/response at the central hub is usually a small number of characters in and a larger number of characters out. When obtaining space capacity from a small earth station network operator, the required capacity can be ordered independently in each direction. Thus, applications requiring various inquiry/response ratios can be ordered separately in satellite service.

2. Current VSAT Applications

An increasingly popular application is business TV - video broadcast for such services as employee training, sales presentations, and product introductions. One way video service is usually supplemented with dial-up or leased lines for queries from receiving sites. Similarly, users also employ one-way satellite service and leased lines for remote database updates with low volume queries. With higher performance and dropping prices, interactive video-conferencing over VSAT has also become more popular. Faced with alternative traveling and boarding costs for centralized meetings, VSAT-based teleconferencing is a valid, economical alternative.

For instructional and educational purposes, VSAT video broadcasting brings valuable instructional programs to the instructors and students. Subscribers to educational services receive the latest information technology and bring faculties and students face to face with leaders in technology. In addition, VSAT broadcast services allow institutions of higher learning to receive information to improve their current knowledge bases with the latest in technology and advancements in all fields of learning.

Interactive VSAT systems allow businesses as well as learning institutions to exchange information. Learning institutions can build a wealth of up-to-date information through interactive data and video two-way broadcasting. Through these systems, even remote learning institutions would have access to the latest teaching information. In addition, training for business, government, education, etc. can be conducted using video two-way broadcasting. Centralized training seminars can be conducted over VSAT video networks for various organizations.

A few examples of this new technology include: Wal-Mart VSAT Network, NICNET, and Chrysler's Network. The Wal-Mart network supports two-way data and voice with one-way video communications. The video capabilities are used for sales training of store personnel, departmental videos, and inspirational speeches by Sam Walton himself. NICNET is India's VSAT Information network which links all state capitals and regional centers with NIC headquarters. The system is used for the collection, processing and distribution of statistics throughout the 5000 centers. Chrysler's network connects the automakers headquarters with the 6000 dealerships and corporate facilities throughout North America. In addition to supplying real-time database access for sales and repair information, the network also supports video broadcast which is used for management communications and training sessions on subjects such as customer service and engine repair. [Ref. 3:pp. 52-3].

3. Future VSAT Applications

The future use of VSAT systems will increase significantly as prices decrease and new innovative applications are developed and matured. The heavy reliance on satellite delivery for TV and radio programming will continue. The advent of high powered Direct Broadcast Satellite systems will increase the number of TV Receive Only dishes found at homes, principally because of the reduced size and cost. Small dishes will also be used for interactive voice and data services using VSAT with Ku band. Mobile satellite services will also come into wide use, where the users in moving vehicles and remote locations can access the public networks for voice and data services. Earth stations with satellite service will continue to serve as effective backup to terrestrial transcontinental and transoceanic cable systems and provide reliable alternative routes for communications. [Ref. 1:p. 323].

A future look at possibilities in the maritime environment reveals opportunities for the private and governmental sectors. Currently, COMSAT provides, via INMARSAT, satellite and coast earth-station services for ships at sea, offshore drilling platforms and international land mobile applications virtually anywhere in the world. Refer to Figure 3 illustration of Marisat Satellite System. Using smartcards, debit cards that store a cash value, to record available phone time, COMSAT provides a method for charging customers by having them initially purchase a card and incrementally reducing its value for the duration of their call. This eliminates surprise credit card bills, but more importantly, relieves the ship's radio room of placing, timing, and collecting for personal calls. In addition, the ability to disable the phone for ships business is an invaluable addition. [Ref. 4:pp. 10-11]

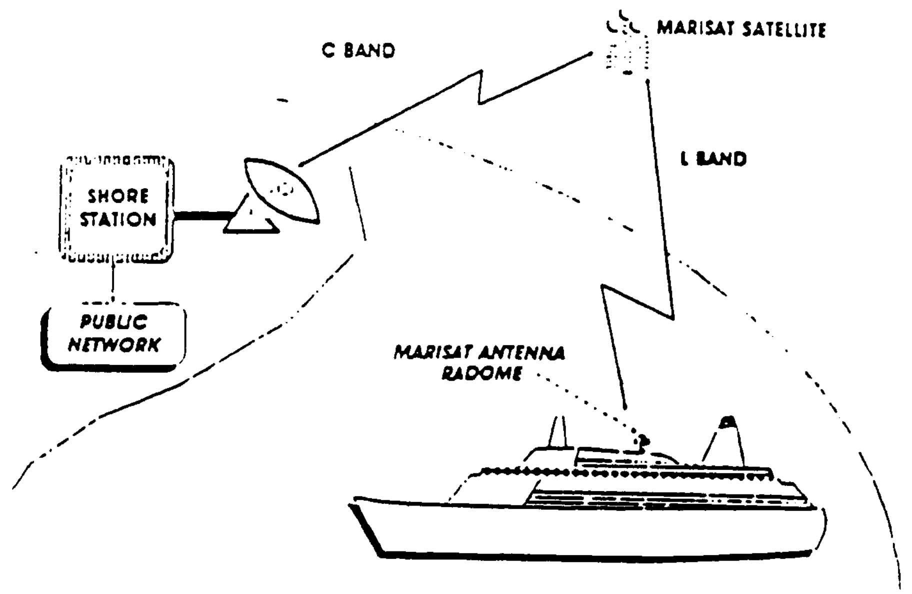


Figure 3 Example of L-Band Service Using the Marisat Satellite System [Ref. 4:p. 22].

III. REQUIREMENTS ANALYSIS

A. TOKEN-RING LAN

1. AS Department Token-Ring Network

The AS Department IBM Token-Ring network uses baseband transmission and operates at 4 Mbps (currently) and 16 Mbps (future). The transmission medium used is data grade cable (shielded twisted pair) which connects 18 microcomputers around the "ring". Three of the microcomputers function as network servers and the others as user computers that share resources. Refer to Figure 4 as of July 1991.

2. Traffic Requirements

For receive only and interactive services, VSAT terminal specifications must meet the performance and standard specifications of the NPS AS Department Token-Ring LAN. Terminals must not exceed subscriber speeds of 19.2 Kbps, terminals must provide atleast two output ports, and ports must be compatible with EIA-232D synchronous and asynchronous electrical interface.

All code/decode and protocol conversion must be performed by the VSAT terminal equipment. Schematic should support device independence and optimize flexibility and future expansion of services.

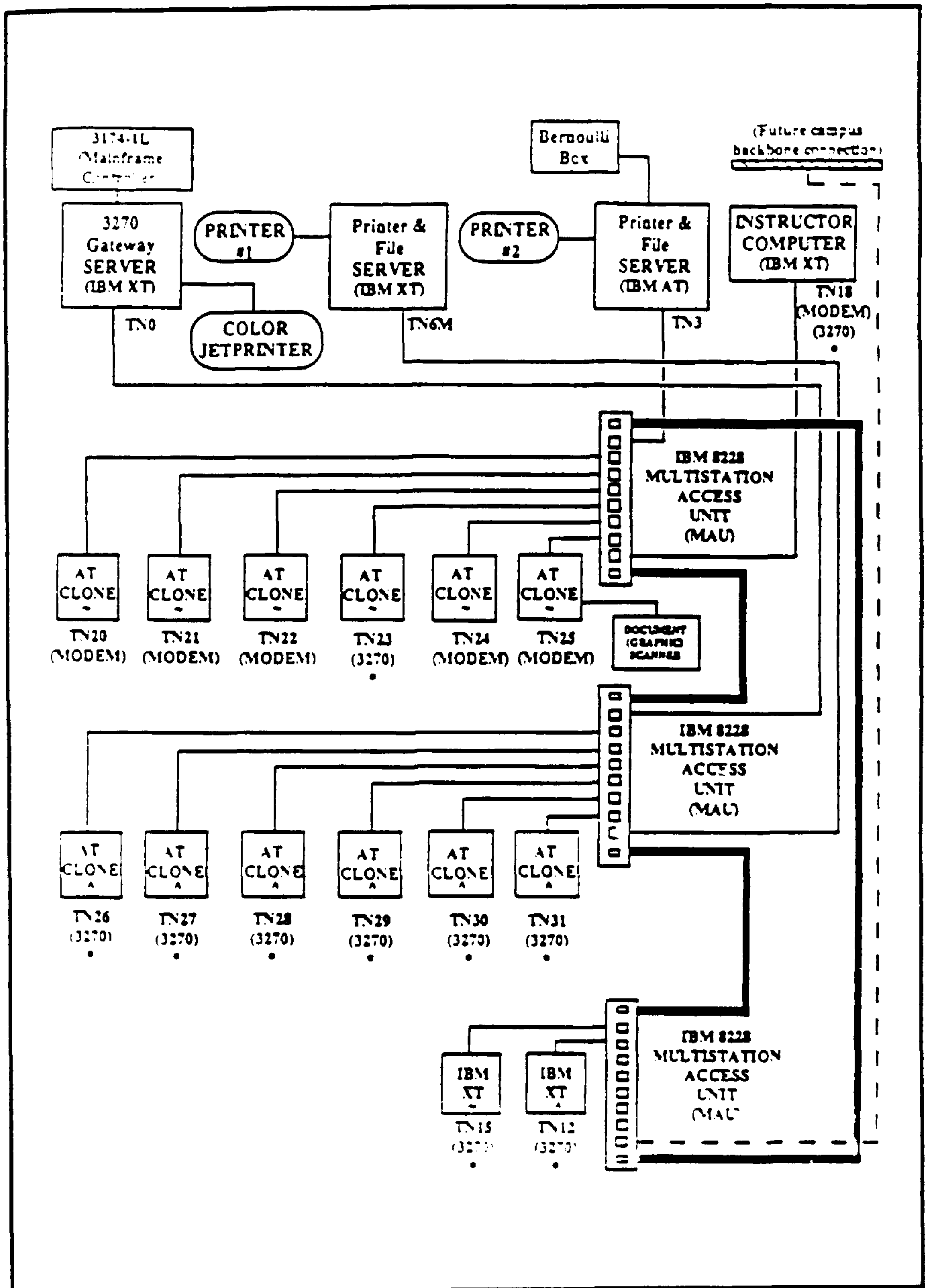


Figure 4 NPS AS Department IBM Token-Ring LAN.

B. OPERATION OF VSAT

1. Satellite Communications Companies

There are currently ten satellite owners and organizations offering satellite services within the United States (See Appendix B). "These ten operators represent 31 in-orbit satellites or 615 transponders. The transponders include 462 in C-band and 164 in Ku band" [Ref. 5:p. 125]. A majority of the transponders are C-band. Note the shuttle disaster interrupted Ku band satellite launches. Almost half of the transponders are dedicated to video services, about 25% are dedicated to voice, and 7% are dedicated to data traffic. The remaining transponders, approximately 18%, are inactive. [Ref. 5:p. 125-6]

Four factors should be considered in evaluating satellite services and selecting earth station equipment: availability, access method, transmission performance, and earth station equipment.

In evaluating a satellite service that supplies carrier-owned earth stations, availability is measured in circuit reliability. This is measured as a percent of error-free seconds in digital services, and percent of availability within specified noise limits for any analog services. In addition, any suspected outages due to solar radiation or eclipse should be considered. [Ref. 5:p. 122]

Satellite carriers employ the use of various coding and apportionment techniques to increase the information carrying capacity of their system. Some techniques can result in congested traffic during peak loads. This sometimes can block user access to the system as well as increase delay periods. Users need to evaluate the methods carriers use to apportion access, determine if blockage is possible, and measure transmission performance to meet users objectives.

The carrier's loss, noise, echo, and envelope delay should be evaluated according to the criteria used for basic transmission concepts. Evaluation results should be directly compared to the users performance objectives.

Earth stations should be evaluated by the following criteria: [Ref. 5:p. 122]

- Equipment reliability
- Technical criteria, such as antenna gain, transmitter power, and receiver sensitivity, that provide a sufficient reliable path to meet availability objectives.
- Antenna positioning and tracking equipment that is automatically or manually adjustable to compensate for positional variation in the satellite.
- Physical structure that can withstand the wind velocity and ice loading effects for the locale.
- The availability of radome or deicing equipment to ensure operation during snow or icing conditions.

The satellite company selected for the NPS AS Department. VSAT would meet above criteria for availability, access, transmission and earth station equipment standards.

2. Physical Layer for VSAT Operation: Access Method

Network protocols for VSAT communications define the procedures for the transmission of data between the VSAT and the hub. The transmitted data can be divided into information for managing the network and user information. This data can be transmitted via packet services or circuit services. Packet services can be further divided into datagram and connection-oriented services. Datagram services are delivered with a limited reliability, namely packets out of sequence or duplicates. and connection-oriented services guarantee sequential delivery with no packet duplicates.

Since most VSAT networks are star configured and not mesh, VSAT-to-VSAT communications is not possible without going through the hub. Most VSAT networks use a single outband carrier for data transfer from HUB to VSAT, and one or more lower bit rate carriers operating in some form of Time Division Multiple Access (TDMA) or Code Division Multiple Access (CDMA) are used for traffic from VSAT to HUB.

When the duty cycle of the traffic generated by these data terminals is very low, less than 5 to 10 percent, methods for sharing satellite channels among a number of users requiring packet bursts are used. These methods fall into four broad categories: Code Division Multiple Access, Packet Reservation TDMA, Fixed Allocation TDMA, and Random Access TDMA. The exact method of channel sharing a network utilizes is determined by the data communication applications for which it is designed. [Ref. 6:p. 35]

With the CDMA method, VSAT's share the same inbound carrier with each VSAT identified by a unique sequence of symbols to represent each bit to be transmitted. This method has lower transponder utilization and is suited for lower data rate applications. Also, it's used for applications requiring spectrum spreading for frequency coordination (C-band VSAT).

In packet reservation TDMA systems, The VSAT sends a request for a data slot to the HUB and only transmits upon receiving the assigned slot. This method has a three satellite hop delay before a data packet can even reach the HUB. [Ref. 7:p. 11]

In the third method, Random Access TDMA, satellite channels are accessed by a VSAT in randomly chosen time slots. This allows for low response delay as long as shared random access channels are operating at a throughput of less than 25 to 30 percent [Ref. 6:p. 36]. Any increase in throughput will cause congestion and lead to long delays.

The satellite carrier provides the communication interconnection at the physical and data link/network layers of the Open Systems Interconnection (OSI) model. The designated server on the Token-Ring network interfaces directly with the VSAT indoor controller unit at the data link and network level, with physical connection made at the physical layer. Various tasks must be completed at each layer before data can be successfully transmitted between the controller unit and the Token-ring network.

The data link and network layers depend on which host/network the VSAT link leads to: IBM Host, X.25 Packet switched network, or remote LAN personal computer. All necessary protocol conversion is accomplished by the indoor controller unit with respect to the appropriate input/output connection ports at the physical layer.

C. HARDWARE REQUIREMENTS AT THE INTERFACE

1. Outdoor Equipment

VSAT outdoor equipment includes for receive only: an antenna for receiving and or transmitting, a low noise amplifier for reception and a downconverter for frequency conversion from microwave to intermediate frequencies. For transmitting capabilities, additional equipment is required: an upconverter for frequency conversion from intermediate to microwave frequencies, and a solid state power amplifier for boosting signals for transmission.

a. Antenna Configurations

Two antenna models for VSAT purposes are currently available on today's market: the prime-focus-fed parabola, and the cassegrain. See Figure 5.

The prime-focus-fed parabolic reflector is usually the least expensive and easiest to install. It operates like a reflecting mirror, in that it produces a beam of parallel

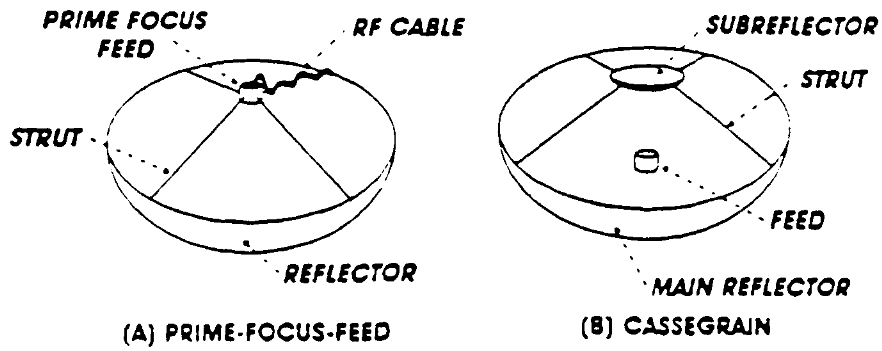


Figure 5 Earth Station Antenna Configurations Used for Receive-Only and Two-Way Communications [Ref. 4:p.222].

rays originating from a source or focal point. This source is the feed horn and is positioned with struts at the focus of the parabolic reflector. Cables or waveguides positioned along the struts join the feedhorn and the outdoor electronics, which does result in some loss in outdoor unit efficiency. A variation in this design is the offset-fed parabolic reflector. Here, the feedhorn is at the end of a hook-shaped piece of waveguide which extends from the vertex of the parabolic reflector. This avoids blockage of the main beam and increases efficiency of the reflector.[Ref. 1:p. 222]

The cassegrain reflector addresses many of the problems of the prime-focus-fed antenna. It operates similar to a telescope, in that the focus of the parabola is directed back by a hyperbolic subreflector to a point at the vertex of the center of the parabolic reflector. [Ref. 1: p.223]. This eliminates the need for cables or waveguides between the feedhorn and the outdoor electronics, which optimizes the outdoor units performance. The same variant using a piece of wave guide extending from the focus to the vertex is also used to eliminate main beam blockage and improve antenna efficiency.

b. Low Noise Blockconverter

The outdoor electronics for a receive only VSAT include a downconverter and low noise amplifier, which combined makes up a low noise block converter.

Since the transmitted signal is very weak when received, it must first be amplified to a level that can be processed for communication. A low noise amplifier does this without burying the signal with internal amplifier noise. Most ground stations today utilize solid state low-noise amplifiers using field effect transistors (FETs) manufactured from gallium arsenide (GaAs) semiconductor material. The devices prove to be less noisy and extremely rugged and reliable [Ref. 1:p. 106].

VSATs and small receive-only earth stations integrate the LNA and the downconverters into a single unit: Low Noise Blockconverter (LNB). By combining the electronics, costs are reduced and the electronics can be offered in a single multi-functional unit.

c. Transmitter option

A transmitting option can be added to most receive-only VSAT outdoor units with the addition of an upconverter and a higher-powered solid state power amplifier.

Intermediate radio frequencies (IF) need to first be converted to microwave signals. This is done using an upconverter, which uses a microwave mixer and a local oscillator (LO). Translation is made by a mathematical rule which states that the output frequency equals the sum of the input IF frequency and the frequency of the LO. The IF or RF carrier band is fixed and the LO is usually assigned.

Once the signal has been converted for transmission, it needs to be amplified sufficiently to complete the satellite link. This is accomplished using a solid state power amplifier capable of boosting microwave signals to transmitter link levels. Refer to the outdoor equipment phase of Figure 6.

2. Indoor Equipment

VSAT indoor units can be broken down into functional groupings: signal processing, multiple access, packetization, networking, protocol handling, and multiplexing. Refer to Figure 7 Block Diagram. All these functions are carried out in one or more compact electronic boxes about the size of a personal computer. These units are located in the building being serviced.

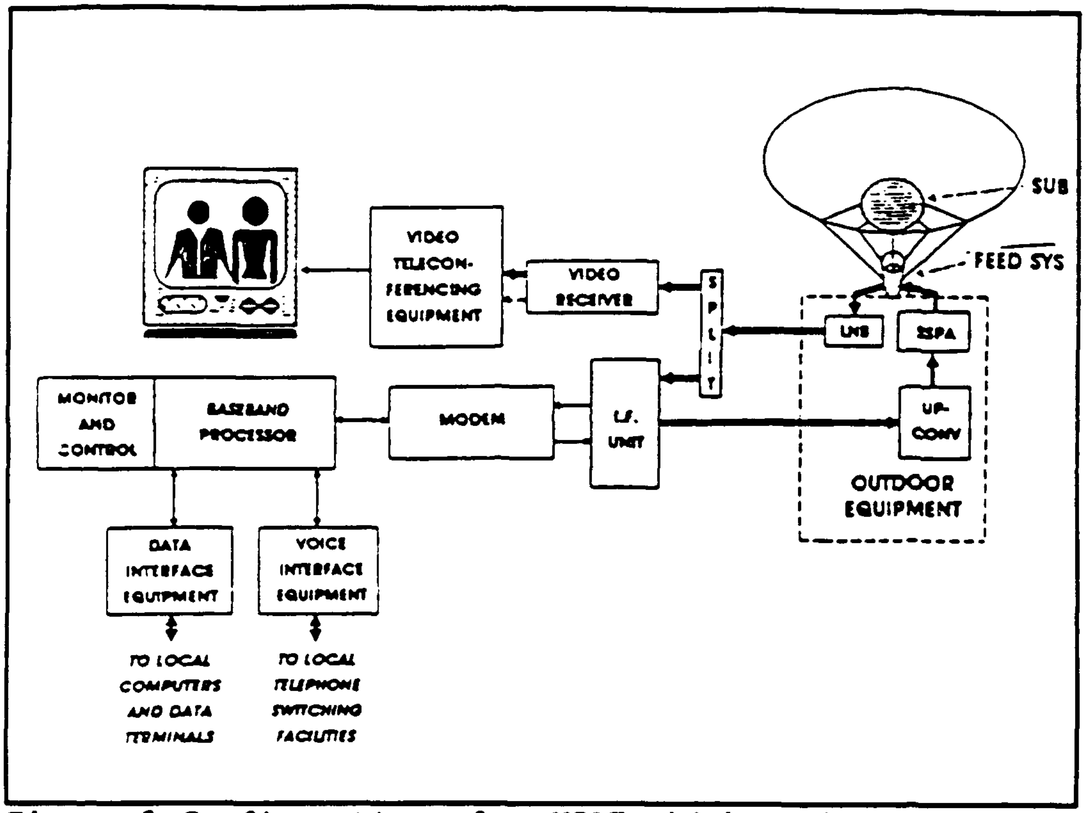


Figure 6 Configuration of a VSAT which combines Two-Way Voice and Data with One-Way Video.

The indoor unit processes the signals received by the antenna and outdoor electronics. The indoor unit also provides all the specialized functions for converting the signal to the data outputs. The unit contains the satellite modem, codec and control circuits, network and protocol processors, status monitoring unit, and a power supply. Connectivity between outdoor and indoor equipment is accomplished using an interfacility link cable. This coaxial cable also supplies low-voltage direct current to the outdoor electronics.

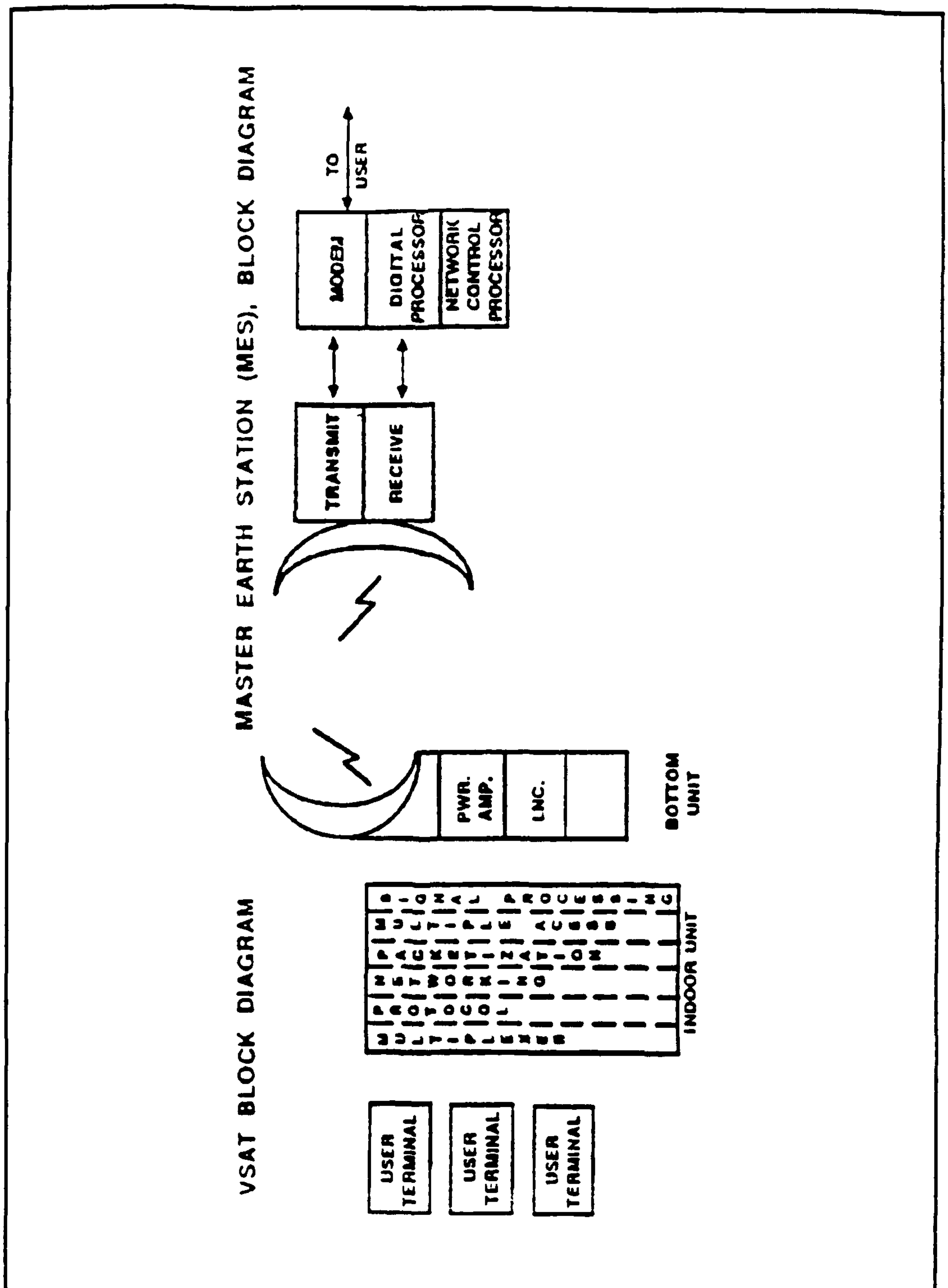


Figure 7 A VSAT Earth Station Communicating with a MES in a Star-Type Network [Ref. 6:p.120].

a. Satellite modem

The satellite modem both acts as the modulator and demodulator for the indoor unit. The modem that transmits the signal is the modulator which puts some form of intelligence on the carrier wave. In contrast, the modem that interprets that signal is the demodulator. The modem has a digital and an analog side. The digital side goes toward the terminal or computer, whereas the analog side goes toward the communication circuit.

b. Codec and Control Circuits

A codec or coder/decoder performs code conversion, the software or hardware conversion from one code format to another. Code conversion is available from any code to any code. The VSAT codec converts the carrier's coded signal to a format that can be processed by the network user computers.

c. Network and Protocol Processors

A hardware protocol converter box converts the communication protocol used by the satellite carrier to that protocol required for the computer network. For example, some protocol converters allow asynchronous terminals to communicate with IBM host computers which use synchronous data link control (SDLC) or binary synchronous communication (BSC) protocols. Some of the typical data link level protocols are High-level Data Link Control (HDLC), Synchronous Data Link

Control (SDLC), Binary Synchronous Communications, and the protocols used by microcomputers,[Ref. 8:p. 322]

Network protocol converters are used for access and management of data transmission onto the communication carrier network. This is a separate function that does not involve the Token-Ring network and does not require any additional OSI protocols for carrier network layer functions.

d. Status Monitoring Unit

The status monitoring unit is used by the satellite carrier as part of their network management software. The operator at the master earth station or hub can provide both link level and system level control. The link level monitors active networks, turns up new sites, performs diagnostics, and interfaces with user equipment. The system level monitors the earth station or hub, which results in immediate identification of communication problems and pin points network inefficiencies.

D. SOFTWARE REQUIREMENTS AT THE INTERFACE

In determining the software requirements for communications between the satellite carrier and the Token-Ring network, the seven-layer Open Systems Interconnection Reference Model (OSI) developed by the International Organization for Standardization (ISO) needs to be examined to determine which layers are pertinent and which layers are to be addressed solely by the carrier. The OSI model serves as a logical framework of protocols for computer-to-computer communications and to facilitate the interconnection of networks.

1. OSI Seven Layer Reference Model

The OSI seven-layer model is used as a plan by which communication software is developed. "The widely implemented OSI model facilitates control, analysis, upgradability, replacement, and management of the resources that constitute the communication network" [Ref. 8:p. 317]. In addition, it helps to develop hardware and software for linking incompatible networks, because protocols can be addressed at one layer at a time. The use of layers in designing network software and various applications is a powerful tool.

The OSI seven layers include: physical, data link, network, transport, session, presentation, and application layers, as in Figure 8. The physical link takes place at the first layer where data bits are physically moved. The other six layers are "virtual" links, in that the links are only theoretical; physical data bits do not move between them. Their purpose is to define the various functions which must be performed when two computer devices want to communicate. These functions are divided into tasks which are completed at a hierarchy of layers. As all tasks are completed at various layers, control is passed on to each successor layer until the physical layer is reached, where the data is then transmitted.

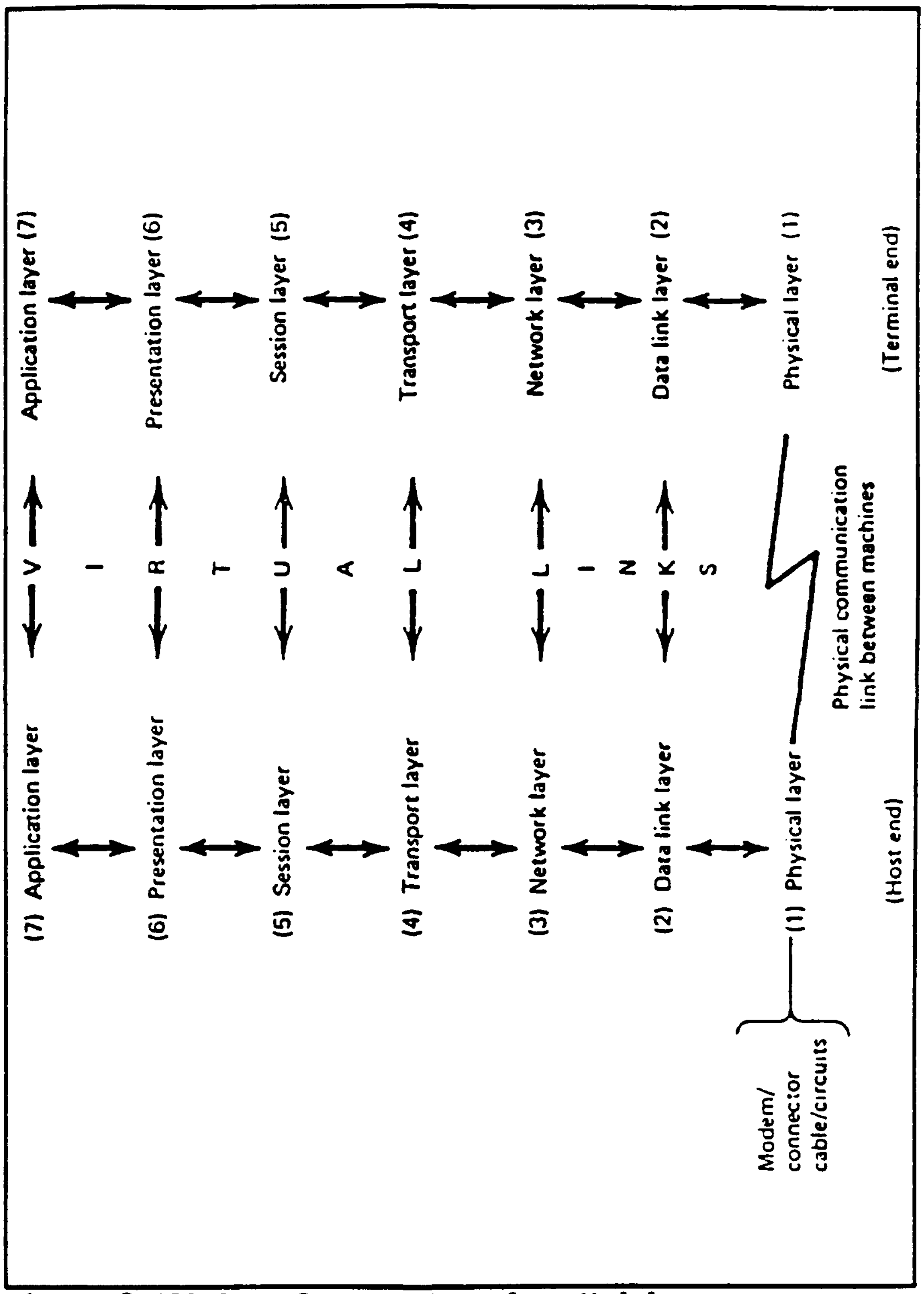


Figure 8 ISO Open Systems Interface Model.

2. Physical Layer

The physical layer is mainly responsible for transmitting data bits over a communications circuit. The primary purpose of this layer is to define the rules for sending and receiving bits so that a 1 bit sent is recognized as a 1 bit received. This layer is the actual communication circuit. At this layer, factors include: electric voltages, timing factors, full or half duplex transmission, rules for establishing initial connection, how to disconnect when transmission is complete, and connector cable standards. The tasks of actual physical, electrical, and functional interchange that establishes, maintains, and disconnects the physical link are the major concerns at this layer.

The physical connection by EIA-232D electro-mechanical interface cables establishes the first layer of communication. This physical layer protocol is handled in conjunction with modems, communication circuits and connector cable standards; the EIA-232D mechanical interface with 25 pin connection utilizes EIA (Electronic Industries Association) standards for electrical and functional characteristics of interface equipment.

The indoor unit supports four protocol conversions for SNA/SDLC, ISO HDLC, BISYNC, and CCITT X.25 protocols with four input/output ports designated by protocol interface. Each EIA-232D mechanical interface must be fitted to the correct port for successful communication between the various host/networks and the AS Department Token-Ring LAN.

3. Data Link Layer

The data link layer manages the transmission of data over the circuit established in the physical layer. A major concern at this layer is the transmission of error-free data. The layer accomplishes this by breaking input data into frames or blocks, transmitting these blocks, and processing acknowledgement frames that are sent back to verify receipt of these error-free blocks. It is the data link layer that gives meaning and structure to the serial streams of data transmitted at the physical layer.

This layer requires intelligence or software which is located in some type of programmable device: VSAT indoor controller unit. The data link layer establishes and controls the physical path of communications before sending the data block down to the physical layer below it. This layer assembles the message into a frame and adds error detection, message type, and other control characters. The layer's priorities include:"... error detection, correction and retransmission, definition of the beginning and end of the message, resolution of competing requests for the same communications link, and flow control" [Ref. 8:p. 322]. Some of the typical data link protocols are: High-Level Data Link Control (HDLC), Synchronous Data Link Control (SDLC), Binary

Synchronous Communications (BSC), and the protocols used by microcomputers.

The protocol interface used for the VSAT indoor controller and the Token-ring network supports typical data link protocols. The VSAT indoor controller unit is configurable to support SDLC, ISO HDLC, and BISYNC standard protocols. The Token-ring network server computer supports typical microcomputer data link protocols. Using SNA/SDLC, Figure 9 demonstrates the remote bridge which connects the VSAT and Token-Ring network. The physical layers are connected via EIA-232D connector cables. The data link layers are virtually linked by the controller SDLC protocol and the microcomputer's logical link control and medium access control protocols. All network and carrier protocols necessary for data transmission from the VSAT are handled by the indoor controller.

4. Network Layer

The network layer provides services that transport data through the network to its destination host/network. It controls the operation of the combined layers 1, 2, and 3. The third layer performs the packet switching network function, which accepts messages from the host computer, converts them to packets, and sees to it that the packets get addressed and directed toward their destination.

> " It is at this layer that your message, which starts out in the host mainframe computer, is cut into packets. Then

> it is passed down to the data link layer, which frames it and passes it down to the physical layer, which in turn pumps the data bits over the communication circuit to wherever the packets are addressed" [Ref. 8:p. 322].

The network layer is addressed when data link and network layer control is needed. When access to a public packet switched network is required, a common interface used is CCITT X.25. The protocol interface used for the VSAT indoor controller and the Token-Ring network supports the CCITT X.25 interface protocol. Unlike the data link protocols, X.25 requires network layer functions and combined control of OSI layers 1, 2, and 3.

5. Synchronous Multipoint Protocol Interfaces

Many VSAT applications are an alternative to an already running terrestrial network counterpart and involve the use of synchronous point-to-point and multipoint protocols such as IBM'S SDLC, BISYNC or ISO HDLC. These link level protocols allow multiple communications devices to share a common communications facility by using a polling/select process.

Synchronous Data Link Control is a more modern protocol concept that reliably moves data from point-to-point to the data link layer. SDLC is a primary division in procedures in High Data Link Control (HDLC), which is standardized by the ISO and CCITT (Consultative Committee on International Telegraph and Telephone) [Ref. 6:p. 44]. When used as an interface to a VSAT network, the protocol's NRM

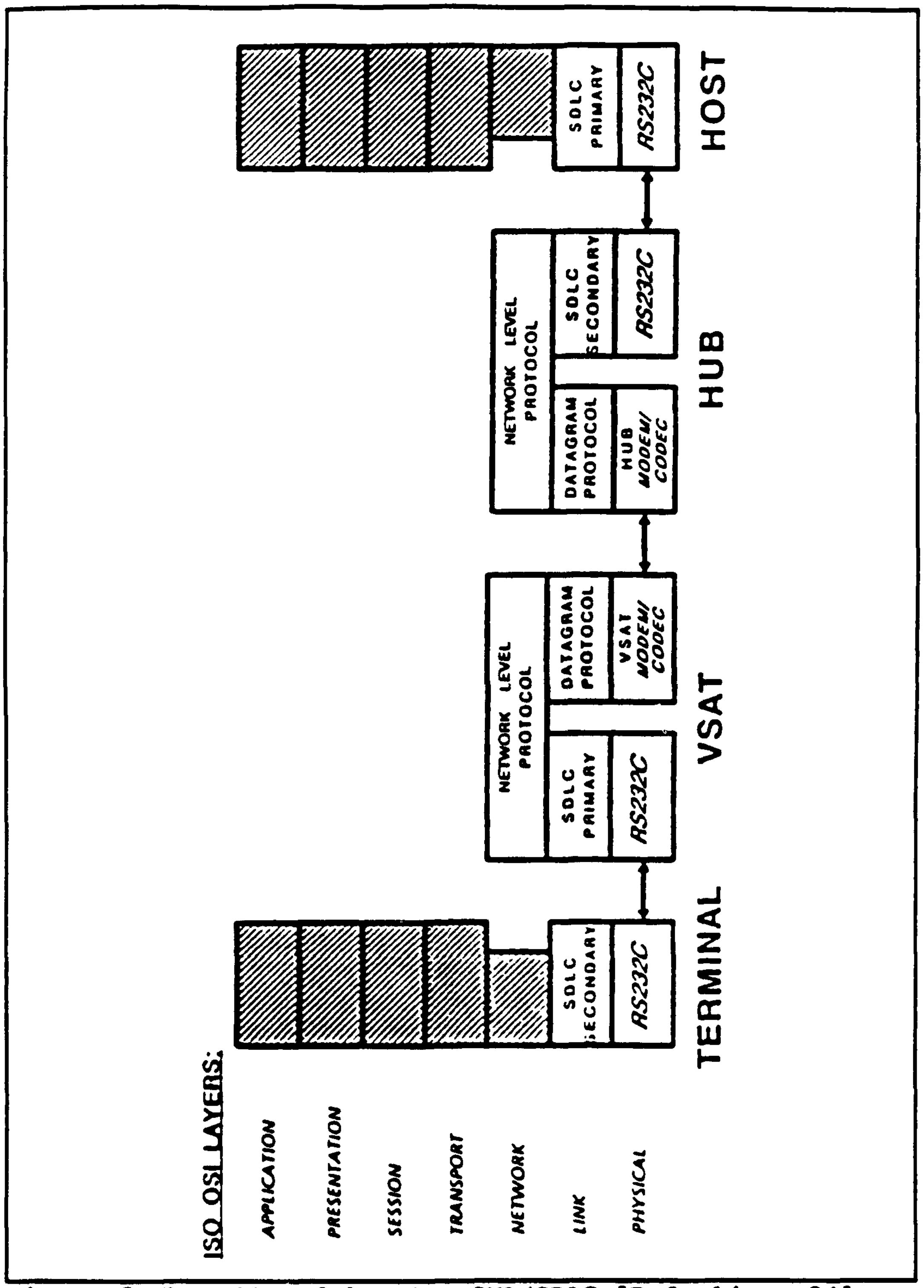


Figure 9 The ISO Model Using SNA/SDLC [Ref. 14:p. 34].

(normal response mode) assigns the host as the primary and the terminal as the secondary station. All data transfers are initiated by the host and data is solicited from the secondary station by a polling process.

In the Binary Synchronous Communications protocol, the polling, selection and data transfer operations between the master (primary) and tributary (secondary) stations is similar to SDLC. The master station continuously solicits data from the tributary stations by sending a polling sequence which contains the unique address of the each tributary. When the tributary needs to send data, the data is sent in response to the next poll. When the master station needs to send data to a tributary, it uses a select process which is followed by a data *string*. *To detect* errors, a block check sequence is appended to the end of each message. If an error is detected, a station responds with a NAK (negative acknowledgement) or with no response, which repeats the selection process. Thus, BISYNC doesn't permit multiple unacknowledged frames and forces the system to stop and wait. [Ref. 6:p. 45]

6. CCITT X.25

The X.25 protocol is an international standard for connecting computers to packet switched networks.. It's second layer LAP B, is compatible with IBM's SNA/SDLC, with frames virtually equal. X.25 is a bit-oriented protocol specifying the structure, content, sequencing, and error handling of messages transmitted over packet-switched networks. This protocol refers only to the first three layers of the OSI model. Some common interfaces which utilize CCITT X.25 protocol include: User/ Defense Data Network (DDN), and User/Public packet switched networks.

IV. DESIGN

The functional design of the VSAT terminal equipment and the physical/electrical interface between VSAT and Token-Ring network is divided into unique component specifications, interface specifications, and the integrated network. The functional design includes a broadcast/receive-only and an upgrade for interactive service with potential connectivity for video broadcast/receive-only capabilities.

A. COMPONENT SPECIFICATIONS

1. Outdoor Unit

a. Antenna Configuration

An antenna configuration for initial broadcast/receive-only service and future interactive service requires a slightly larger antenna than for restricted receive-only VSAT. For the use of C band and Ku band, antenna diameters are in the range of 1.2 to 1.8 meters. Even though transponder capacity is low, the spread spectrum technique and superior propagation characteristics of C band could also permit the use of antennas in the range of 0.6 to 1.2 meters [Ref. 1:p. 249]. For this demonstration, antenna configuration will have a diameter in the range of 1.2 to 1.8 meters. Refer to Figure 5 to see VSAT antennas.

In order to maximize the benefits of off-set parabolas and cassegrain antennas, a combination of both will be used. This hybrid antenna will permit the feedhorn and electronics to be mounted below the reflector and out of the way of the main beam. This will maximize beam signal strength and minimize noise contribution from the electronics.

b. Outdoor Electronics

The outdoor electronics will be implemented in a standard "black box" supplied by the carrier, which will be broken into the receive section and the transmit section. The outdoor unit will be modularized for easy upgrades with additional connectivity for future additional capabilities (interactive, video receive-only).

For receive-only units with upgradability, outdoor electronics include: low noise amplifier, frequency down converter, and interfacility link cable. In order to maximize efficiencies and reduce cost, the low noise amplifier and frequency downconverter is supplied as an integrated unit, low noise block converter. This unit will receive the carrier signals, process for indoor unit, and send signals to indoor unit for further processing. Specifications for satellite link data rates to each VSAT are between 138.2 kbps and 168.9 kbps. The outdoor-indoor unit link will be supplied as the interfacility link cable. This coaxial cable will also supply power to the LNB via the indoor unit.

For transmitting capability with interactive service, outdoor electronics include: for receive-only section, the same LNB unit for reception; and for transmit section, an upconverter and solid state power amplifier (SSPA). Unlike the LNB, the SSPA and upconverter are separate units. The RF signal is received from the indoor unit and converted to carrier microwave frequency. Specifications for nominal operating frequencies are: for C band, 3.700 to 4.200 GHz downlink and 5.925 to 6.425 GHz uplink; for Ku band, 10.95 to 11.70 GHz downlink and 14.00 to 14.500 GHz uplink [Ref.1:pp. 13,17]. The SSPA then sufficiently amplifies the signal for successful link operation.

c. Video Capabilities

For future upgrade to video receive-only capability, design modularity lends to easy adaptation of video capabilities. The same indoor unit can be utilized with the addition of a splitter to direct the downlink signals to the indoor unit and a video receiver. Additional video-teleconferencing equipment including dial-up or leased lines can combine two-way voice and data with one-way video. Because of the low transmit power and small diameter antenna dish, the VSAT would not be able to transmit video. But for a future alternative which would allow for exploration of two-way video, a way of working around this limitation would be to employ compressed digital video operating at 56 kbps.

"The quality of such a two-way link is significantly poorer than analog FM in terms of its response to rapid picture, but could be acceptable for meetings and pictorial information."[Ref. 1:p .251]

Thus, the initial purchase of an antenna capable of satisfactory interactive links (1.2 to 1.8 meters) and a receive-only outdoor unit would be completely upgradable to future interactive and video capabilities. In addition, two way video for instruction and possible conferences, even with poor response to rapid picture, would be possible with further upgrades. Refer to Figure 6 to see complete VSAT outdoor unit module.

2. Indoor Unit

Proper indoor unit selection is dependent on services required. Indoor unit electronics are "black box" units specifically designed for receive-only, interactive and video capabilities. Because of the modular approach to design, indoor units can be easily upgraded to include additional services by replacement of units with each upward advance in sophistication.

a. Receive-only/Broadcast

For receive-only/broadcast service, an indoor unit capable of processing the signals received through the antenna and outdoor electronics and delivering them in a compatible form to the user is required. The indoor unit's functions include: signal processing, multiple access, packetization, networking, protocol, and multiplexer. See Figure 7. All these functions are virtual to the user and are accomplished by the carrier. The indoor unit will process all received signals and convert them into the form compatible with the specified interface or port. The receive-only indoor controller provides four output ports, configurable for synchronous and asynchronous operations. The indoor unit supports up to 64 Kbps data rates. Refer to Figure 7 to see functional block diagram.

<u>b. Interactive</u>

For interactive VSAT with transmitting capabilities, indoor units include all the functions for receive-only units with the addition of transmit as well as receive capabilities. Specifically, indoor units include: satellite modem, codec and control circuits, network and protocol processors, status monitoring unit, and power supply. In addition to converting all received signals to compatible form for the user, the carrier-supplied "black box" also includes the reverse functions necessary for transmitting data and the onboard monitoring system which allows the carrier master earth station or hub to offer both link level and system level control for monitoring active networks and hub management.

<u>c. Video Capabilities</u>

For future video receive-only capabilities, a separate indoor unit in addition to the interactive indoor controller is required. By introducing a splitter between the downlink electronics unit and the indoor controller, parallel signals can be used: signals for processing for the Token-Ring network and signals for processing for video capabilities. A video receiver unit would receive the signals for video processing. It would include all electronics and processing equipment required for signal conversion. For video-teleconferencing, additional equipment would be required for two-way voice and data and one-way video. Refer to Figure 6 to see VSAT configuration. In addition, for two-way video, a specialized unit for employing compressed digital video operating at 56 Kbps would be required.

B. INTERFACE SPECIFICATIONS

Interface specifications are divided into hardware and software considerations and need to be reconsidered for additional future upgrades.

1. Hardware Considerations

Specifications are required for physical interfaces between VSAT antenna and outdoor electronics, outdoor electronics and indoor controller, and indoor controller and Token-Ring network . All physical interfaces are inter-connections, with the exception of the intra-connection within the outdoor unit.

The intra-connection within the outdoor unit is the connection between the antenna and the outdoor electronics.

In order to maximize efficiency and minimize noise, the electronics are mounted at the base of the feedhorn. The resulting connection has a negligible effect on signal noise and can almost be considered part of a single unit.

The inter-connection between the outdoor electronics and the indoor controller is an interfacility link cable. This coaxial cable can run a maximum of 300 feet. With an interactive system, dual coaxial cables are used to interconnect the antenna module and the controller. Low voltage direct current is supplied via the coaxial cable to the outdoor electronics from the indoor unit.

The input/output interface between the indoor controller and the data terminal equipment utilizes the EIA-232D standard. Electro-mechanical interface is achieved using the EIA-232D connectors with 25-Pin Connection. For receive-only, the indoor unit provides four output ports. For interactive, the indoor unit provides two data port sets, each of which may operate independently using the same or different communications protocols. Each input/output port is designated for a specific protocol and operates in either half-duplex or full-duplex mode at any rate up to 9.6 Kbps (50, 110, 300, 600, 1200, 1800, 2400, 4800, or 9600 bps).

2. Software Considerations

Software considerations should be grouped into three areas: software required to operate the Token-Ring network, software required to manage and operate the VSAT and the carrier's network, and software required to establish and maintain a satisfactory link between the Token-Ring network and the VSAT.

a. Token-Ring Network Operations

The additional software required for the operation of the Token-Ring network with the VSAT link would be the allocation of the transmitted VSAT information to a designated server computer and the management of this new resource. User computers with access to the VSAT information would be designated on the server computer and each user computer's level of access would be stated. This new resource would be managed by a server computer like all resources on the network.

The token-ring access method would not change nor be degraded in its performance by this additional resource.

b. VSAT Carrier Network Operations

The second consideration for the management and operation of the VSAT and the carrier network is completely carrier-supplied and does not require any further installation or maintenance other than that performed by the carrier. The VSAT indoor controller is responsible for converting the received carrier signals to compatible end user format. The VSAT indoor unit performs all the necessary protocol conversion and network management. All these functions are transparent to the end user, who receives the processed information in its final form. Refer to Figure 7 to see indoor unit block diagram.

c. VSAT-Token-Ring Interface

The third consideration is a satisfactory link between the Token-Ring network and the VSAT. The logical link is created at the data link or network level with actual physical connection at the physical layer. The VSAT controller supports: IBM SDLC, IBM BISYNC, and ISO HDLC data link protocols; and CCITT X.25 interface protocol.

For a reliable VSAT connection to IBM mainframe hosts or remote LANs, data link layer protocol must be implemented. The data link protocol (either IBM SDLC, BISYNC, or ISO HDLC) is used for this purpose between the controller unit and the LAN server. Refer to Figure 10 to see Protocol Layer Communications Diagram.

In the case of SNA/SDLC, the LAN server is designated as an SDLC secondary station. The SDLC module within the VSAT terminal assumes an SDLC primary station function, and polls the secondary station for data transfers. Data frames received from the secondary station are routed to the satellite network, which uses its own link level service between the VSAT terminal and the hub. Data frames received at the hub are routed to the appropriate SDLC secondary station emulator and are then routed to the user's SDLC

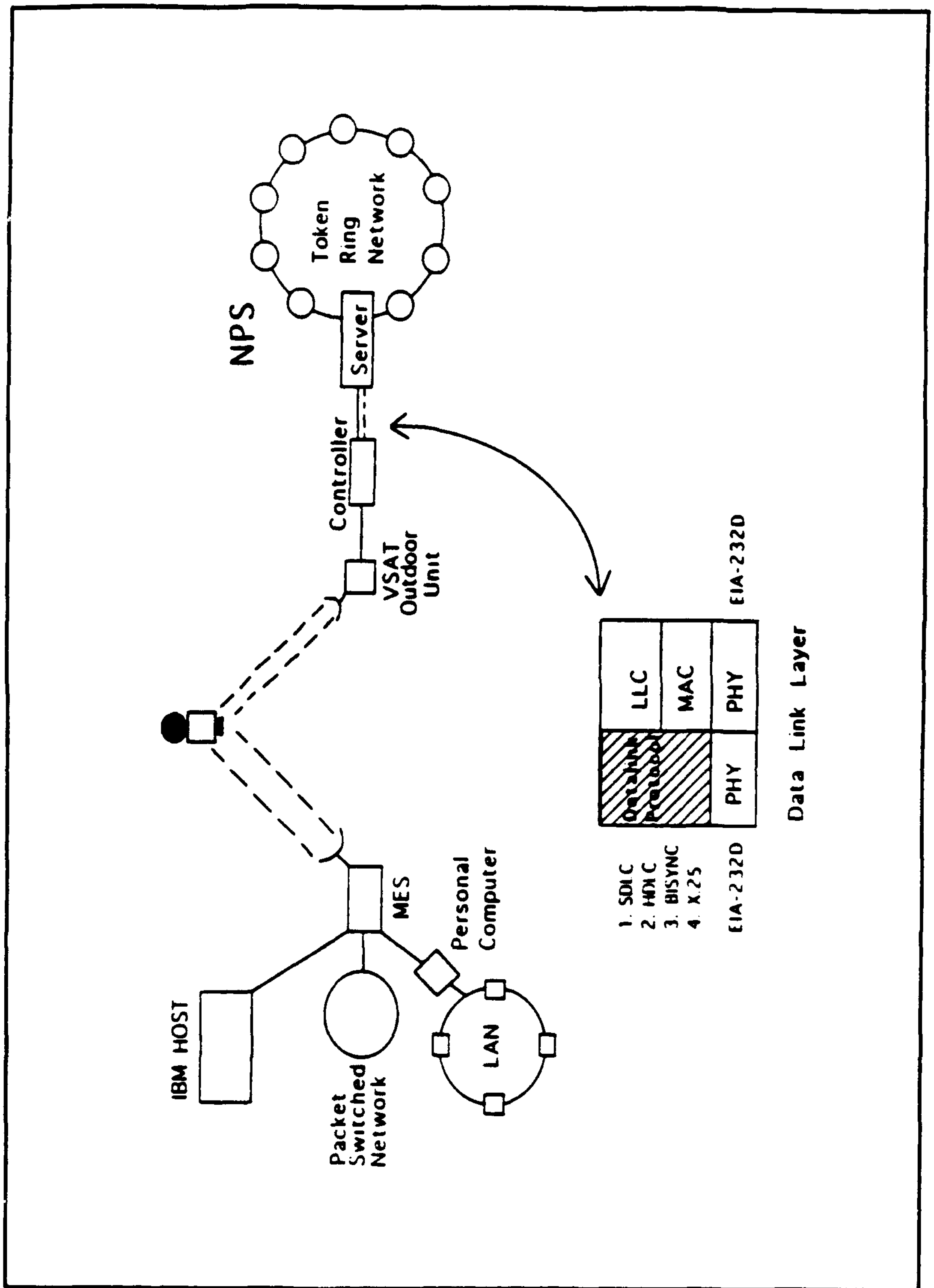


Figure 10 Data Link Layer Protocol Interface.

primary station. As a result, no end-to-end polling is done on the network. All polling is emulated and restricted to local connections within the network.

SDLC protocol breaks the input data into data frames, transmits these frames and processes acknowledgement frames which are sent back to acknowledge the received data. Refer to Figure 11 for a typical SDLC frame format. Within this framework, SDLC protocol performs all error detection and correction services in the data link layer.

Once properly formatted, data is then passed over the EIA-232D interface. Network layer control is not required since the VSAT link is treated as an appendage or additional resource to be shared on the Token-Ring network. Any network functions carried out by the VSAT controller or the Token-Ring network are independent of the link between the two and support complete device independence.

In order to establish a VSAT connection between an X.25 packet switching node and the LAN server, the X.25 port must be used. CCITT X.25 interface protocol defines the first three layers of the OSI model. A summary of X.25 network layer functions include: [Ref. 8:p. 327]

- controls call setup and termination
- identifies the logical channel number chosen by the call initiator
- addresses the called party
- counts packets for charging purposes

Flag 01111110	Address	Control	Message	Frame check	Flag 01111110

Flag - Each frame begins and ends with a special bit pattern (01111110). This flag when at the beginning, references the position of the address and control frame elements and initiates the procedures for error checking. When used at the end, the flag terminates the error checking procedures and may mark this next frame.

Address - This address field is used to identify one of the various terminals. It has an 8 bit field and can contain station addresses, group addresses for several terminals, or a broadcast address for all terminals.

Control - The control field identifies the kind of frame that is being transmitted. Frames can be used for information, acknowledgement, and other purposes to indicate status and maintenance needs, etc.

Message - The message field is a variable length and contains the message or request from the user. It can also contain a general format identifier, logical channel group numbers and packet-type identifiers.

Frame check sequence - A 16-bit cyclical redundancy checking calculation placed in the field by the transmitting station. It's used to ensure data integrity and initiate data retransmisson.

Figure 11 CCITT X.25 frame, also SNA/SDLC frame format.

- starts the transmission over a virtual circuit
- breaks the message into various packets/frames
- prevents network overload by controlling the flow of packets
- determines the path over which the packet is transferred
- provides various security features

Figure 11 also illustrates the X.25 interface. An X.25 packet is encapsulated in the LAP B frame, which is virtually identical to the SNA/SDLC frame. Once properly formatted, the data is then passed by EIA-232D interface.

The LAN server plays the role of a gateway by implementing the Token-Ring protocols (IEEE 802.5, MAC, and physical specifications) on one side and the data link and/or network layer protocols on the side of the VSAT. Refer to Figure 12 to see Network Layer Communications Diagram.

C. THE INTEGRATED NETWORK

The connected Token-Ring network and VSAT is functionally illustrated in Figure 6 and can be expanded to include a video teleconferencing capability with a possible room extension or addition to the present floor plan. The VSAT and Token-Ring network specifications for hardware and software are accompanied with a functional diagram of a VSAT satellite link with a MES. Refer to Figure 6 and Appendix B. The views assume interactive service and can accommodate video capabilities for future expansion of services.

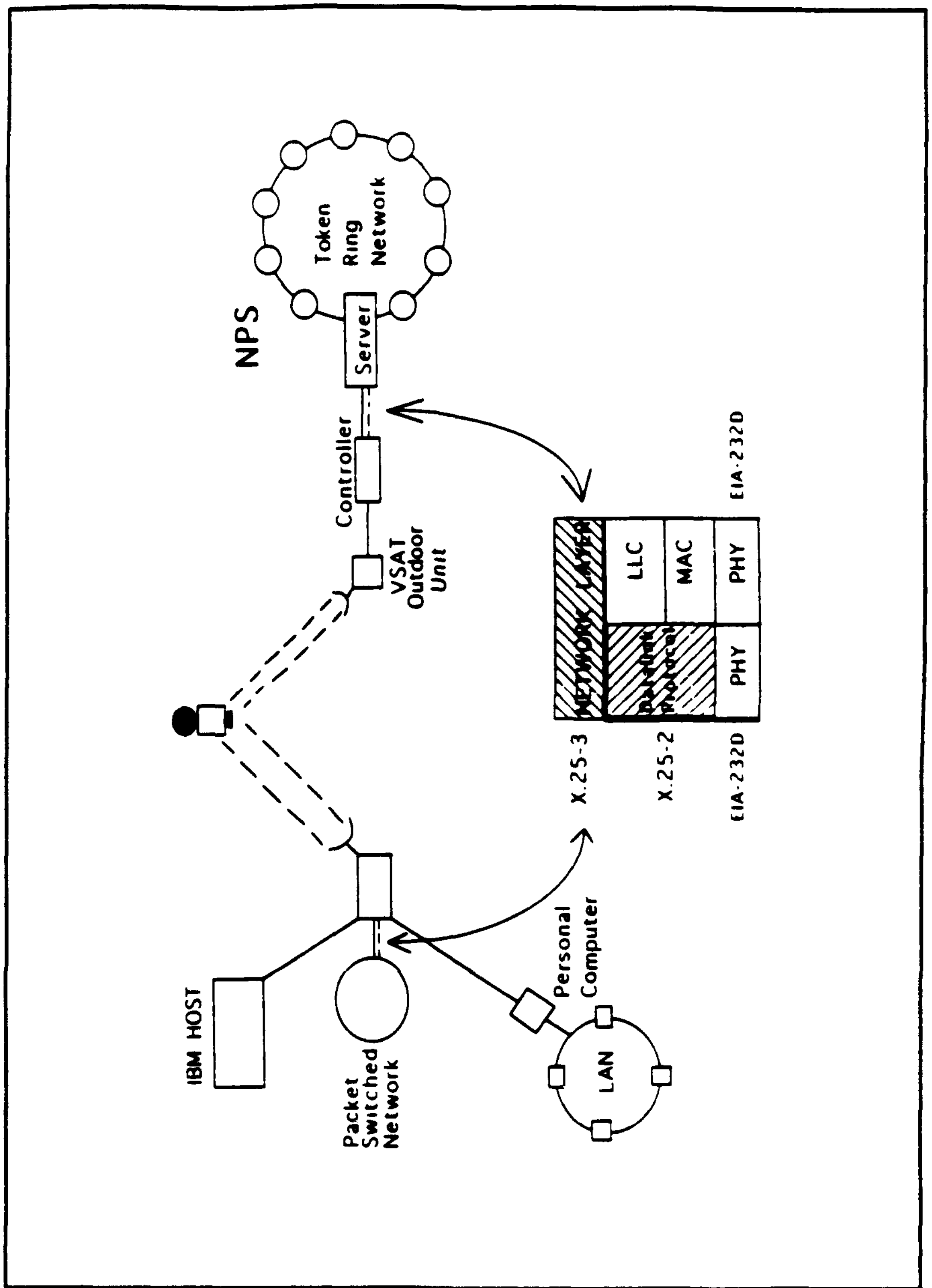


Figure 12 Data Link and Network Layer Protocol Interface.

Terminal design is based on generic models with real world specifications. Terminal design was selected from a generic base model with a range of specifications for performance and configuration.

All physical interfaces are based on engineering standards set by the EIA and all data interfaces are based on protocol standards set by the ISO and IEEE standards committees.

V. CONCLUSIONS

A. SUMMARY

With the ever-decreasing size of antenna apertures and the dramatic improvements in microprocessor technology, the price of satellite technology has come down to consumer level thresholds. VSAT technology has provided the opportunity, not only for CATV and direct broadcasting services, but also for a satellite communications medium for all forms of telecommunications.

The inherent versatility of satellite technology has been demonstrated in a myriad of applications for receive-only, interactive, and one/two-way video services, specifically, the use of VSAT in today's competitive markets, government and private sectors. From direct data broadcasting for company-wide database updates to interactive video-teleconferencing for upper-management executive board meetings that span a continent, VSAT services have proven to be versatile, effective, and economical. Depending upon a company's communications requirements,"...the VSAT network can be cost competitive for networks as small as 100 VSATs" [Ref. 9:p. 34].

To establish a link between a VSAT and a LAN (in this case a Token-Ring LAN), the requirements for the communications link are divided into five general areas: Token-Ring LAN, Satellite Communications company (carrier), Software, Hardware, and Operation of the VSAT.

First, the two independent networks need to be separately identified, defined, and their limitations identified. The Token-Ring network utilizes a token access method in a ring configuration and consists of one or more server computers with various resources connected to a number of user computers. The satellite network is a star configuration of earth stations (includes VSATs) with a master earth station or shared hub. Each network operates independent of the other.

Secondly, both the hardware and software requirements need to be defined for the VSAT station, the Token-Ring network, and the VSAT-Token-Ring interface at the physical as well as virtual OSI layers. The VSAT station consists of the outdoor and indoor units. Equipment includes: for the outdoor unit, an antenna for receiving/transmitting, an integrated unit combining SSPA and downconverter for signal strength amplification and frequency conversion; for the indoor unit, a satellite modem for transmitting and receiving signals by modulation and demodulation, codec and control circuits for code conversion, network and protocol processors for protocol conversion, and status monitoring unit for providing link and system level control.

Once the two networks have been examined and all hardware and software requirements defined, the physical and virtual requirements for interface can be determined.

The hardware and software requirements for interface depend upon which host/network the Token-Ring network is communicating: IBM mainframe host, public packet-switched network, or remote PC LAN. The physical connection is made by EIA-232D connection to the designated controller input/output port that supports the respective protocol conversion. Data link and network layer protocol supported by the VSAT controller includes: IBM BISYNC, HDLC, SNA/SDLC, and CCITT X.25.

Communications requiring data link layer protocols for IBM host or PC LAN links are supported by the VSAT controller, using IBM BISYNC, SNA/SDLC, or HDLC standard protocols. A remote bridge is formed by the VSAT controller and the Token-Ring network. The physical layers are connected via EIA-232D connector cables. The data link layers are then virtually linked by the controller data link protocol and the LAN microcomputer's logical link control and medium access control protocols.

Communications requiring network layer protocols for packet-switched networks are supported by the VSAT controller, using CCITT X.25 standard protocol. Unlike the data link protocols, X.25 requires network layer functions and combined control of OSI layers 1, 2, and 3. The physical layers are also connected via EIA-232D connector cables.

For demonstration purposes, a functional design using generic models and real world specifications was developed for a VSAT link with the AS Department Token-Ring LAN.

The functional design of the terminal equipment and physical/electrical interface of the VSAT and the Token-Ring network was divided into unique component specifications and interface specifications, with a look at the integrated network. The functional design includes broadcast/receive-only and an upgrade for interactive service with potential connectivity for video broadcast/receive-only capabilities.

B. FUTURE CONSIDERATIONS

Tomorrow's Naval officer will be faced with the same data, voice and video challenges that await today's business markets and private sectors. It will be important for him to understand the potential uses of satellite technology and the unique power that future VSAT sites will bring to the user.

A myriad of applications are present today, and will continue to multiply well into the future. A look at near future applications for tomorrow in the broadcasting, interactive, and video markets suggests the important roles that satellite technology and VSAT usage will play in the future.

In the data broadcast market improvements in data rates from a few thousand bits per second to perhaps a million bits per second will provide increased benefits to the users. Not only would the capability of large data transfer be available to the average user, the visual quality of digitized images would greatly improve. This would open the possibility of video capabilities at reasonable expense to the average user, where current usage is restricted to companies with substantial capital investments.

With the advent of improved digital compression equipment, video-teleconferencing quality will improve remarkably. Currently, the quality of 56 Kbps compression is unacceptable, and the more popular 1.544Mbps is generally accepted by users. " It is likely that the quality of 56 Kbps compression will improve to the point where it is equal to the current 1.544 system" [Ref. 1:p. 344].

These few applications are just the tip of a technological iceberg. The future holds many opportunities for increased productivity and efficiencies in services and products. The manager that takes advantage of the future technology for VSAT and satellite communications will remain on the cutting edge of his or her profession.

APPENDIX A. ACRONYMS

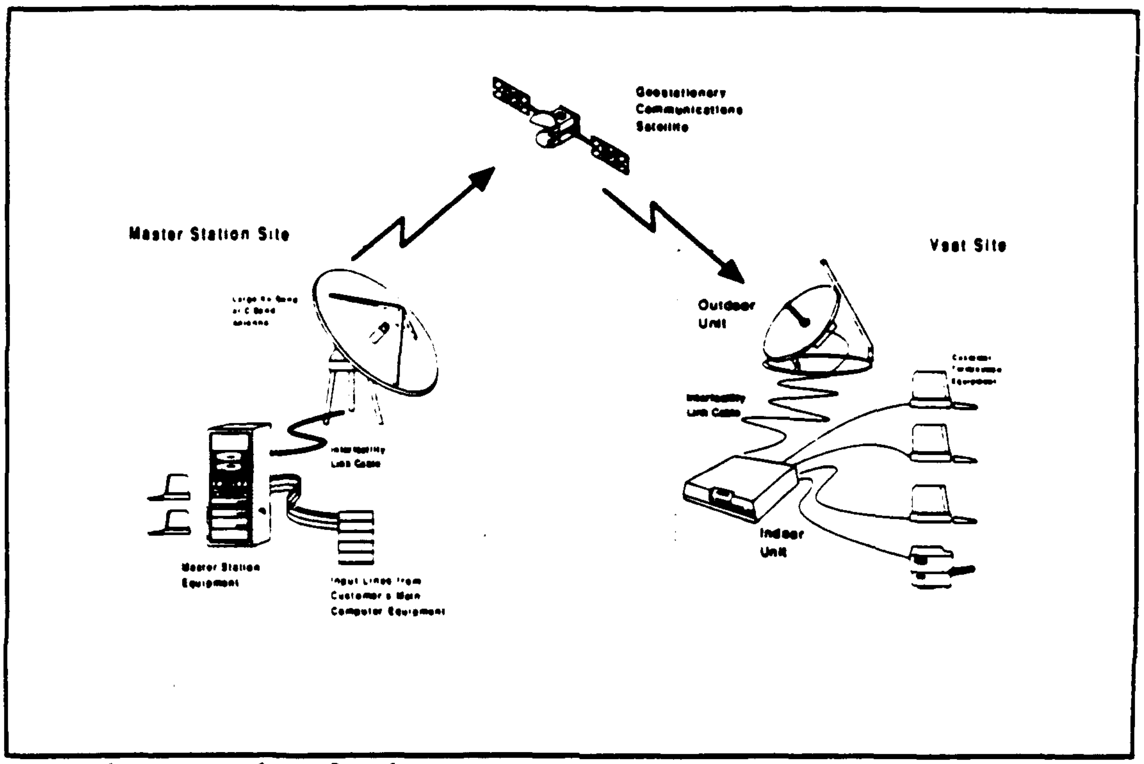
ACK	Acknowledgement of Error-Free Reception
AM	Amplitude Modulation
AS	Administrative Sciences department
ASCII	American Standard Code for Information Interchange
ASYNC	Asynchronous communication
BISYNC	Bisynchronous communication
BPS	Bits per second
BSS	Broadcasting Satellite System
CATV	Community Antenna Television, Cable Television
CCITT	Consultative Committee on International Telegraph and Telephone
CLS	Clear to Send
COMSAT	Communications Satellite Corporation
CPU	Central processing unit
CRC	Cyclical Redundancy Check
CSMA/CD	Carrier Sense Multiple Access with Collision Detection
DB	Decibel
DBS	Direct Broadcast System
DC	Direct current
DCU	Delayed Compensation Unit

DOS	Disk Operating System
DTE	Data Terminal Equipment
EBCDIC	Extended Binary Coded Decimal Interchange Code
EIA	Electronic Industries Association
FCS	Frame Check Sequence
FDDI	Fiber Distributed Data Interface
FDM	Frequency Division Multiplexing
FDMA	Frequency Division Multiple Access
FEP	Front End Processor
FET	Field Effect Transistor
FM	Frequency Modulation
FSK	Frequency Shift Keying
GaAs FET	Gallium Arsenide Field Effect Transistor
GEO	Geostationary Earth Orbit
GHZ	Gigahertz
HDLC	High-Level Data Link Control
IBM	International Business Machines Corporation
IEEE	Institute of Electrical and Electronics Engineers
IF	Intermediate Frequency
ISO	International Organization for Standardization
KBPS	Kilo bits per second
LATA	Local Access Transport Area
LAN	Local Area Network
LNA	Low Noise Amplifier

LNB	Low Noise Block Converter
LO	Local Oscillator
Megabyte	One million bytes
NAK	Negative Acknowledgement
NETBIOS	Network Basic Input/Output System
OSI Model	Seven Layer Open Systems Interconnection Reference Model
PSN	Packet Switching Network
PBS	Public Broadcasting Service
PBX	Private Branch Exchange
PC	Personal Computer
RAM	Random Access Memory
RF	Radio Frequency
RFI	Radio Frequency Interference
RO	Receive-Only
ROM	Read Only Memory
RS232C	IEEE interface specification
RTS	Request to send
SBS	Satellite Business Systems
SDLC	Synchronous Data Link Control
SN	Switching Node
SNA	Systems Network Architecture
SNR	Signal to Noise Ratio
SSPA	Solid State Power Amplifier
TCP/IP	Transmission Control Protocol/Internet Protocol

TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
TVRO	TV Receive-Only
Tymnet	British Telecom's public packet switched network
UHF	Ultra High Frequency
VHF	Very High Frequency
VSAT	Very Small Aperture Terminal
WATS	Wide Area Telephone Service
X.25	CCITT international standard for connecting computers to packet switched networks

APPENDIX B. DESIGN SPECIFICATIONS



Generic Functional Diagram

INTERACTIVE DESIGN

Frequency Bands: C and Ku bands

Receiver: 1.4 meter parabolic offset antenna module

Configuration: Single section antenna includes:

Antenna, waveguide, upconverter, and downconverter.

Size: 69-76 inches wide x 43-47 inches high.

Weight: 142-158 pounds

Operating Temperatures: -40°C to 50°C

Wind: survival 95-105 mph

operating 59-65 mph

Nominal Receive frequency: 4 Ghz

Nominal Transmit frequency: 6 Ghz

Bit error rate: 1×10^{-12}

Outdoor unit-Indoor unit link: Dual coaxial cables interconnect Antenna module and controller (up to 300 feet maximum)

Outdoor Unit: Transmit section includes: upconverter, solid state power amplifier

Receive section includes: low-noise, amplifier/frequency, downconverter (LNC)

Controller: Size: 16-18 inches wide x 20-22.5 inches deep x 5.5-6.0 inches high

Weight: 47.5-52.5 pounds

Power: 125 Volt VAC, 47-63 Hz, 300 W

Operating Temperatures: 0°C to 50°C

Humidity: 0 to 95%

Indoor Unit: satellite modem,

codec and control circuits,

network and protocol processors,

status monitoring unit,

power supply

Indoor Unit (receive-only): signal processor, specialized functions for signal conversion, 4 output ports for synchronous or asynchronous

Input/Output Interface: Input/output channels 2, Mechanical Interface EIA232D (25Pin-Connection), Electrical Interface EIA232D

Data Character Transmission Methods: Bit Synchronous, Byte Synchronous or Serial Asynchronous.

Data Character Size: 5, 6, 7, or 8 bits selectable

Interface Data Speeds (bidirectional): 50, 110, 300, 600, 1200, 1800, 2400, 4800, or 9600 bits/sec.

Satellite link data rate to each VSAT: 146.2-161.3 Kbps
Satellite link data rate from each VSAT: 114-126 Kbps
Protocol Interface: configurable to support standard protocols, includes SNA/SDLC, HDLC, Async, Bisync and CCITT X.25.

APPENDIX C. US Satellite Capacity by Carrier

Operator	Satellite	Freq Band	Transp (C/Ku)	End of Life	Allocation of Transp C/Ku: Video	Voice	Data	Inactive
ALASCOM	Aurora 1	C	24/0	10/92	3/0	13/0	0/0	8/0
AT&T	Telstar 301	C	24/0	1993	15/0	7/0	0/0	2/0
	Telstar 302	C	24/0	1994	10/0	1/0	8/0	3/0
	Telstar 303	C	24/0	1995	2/0	11/0	1/0	10/0
COMSAT	Comstar 2	C	24/0	1985	0/0	0/0	0/0	24/0
	Comstar 4	C	24/0	1988	0/0	0/0	0/0	24/0
	SBS 1	Ku	0/10	11/87	N/A	N/A	N/A	N/A
	SBS 2	Ku	0/10	09/88	N/A	N/A	N/A	N/A
Contel ASC	ASC 1	C/Ku	18/6	08/94	0/1	11/5	6/0	1/0
GE	SATCOM 3R	C	24/0	11/91	24/0	0/0	0/0	0/0
	SATCOM 4	C	24/0	11/92	23/0	1/0	0/0	0/0
	SATCOM 1R	C	24/0	04/93	13/0	3/0	5/0	3/0
	SATCOM 2R	C	24/0	04/93	4/0	11/0	8/0	1/0
	K1	Ku	0/16	11/95	0/4	0/0	0/0	0/12
	K2	Ku	0/16	12/95	0/11	0/1	0/0	0/4
GTE	Spacenet 1	C/Ku	18/6	11/92	13/0	4/18	0/1	1/2
	Spacenet 2	C/Ku	18/6	11/92	0/4	14/0	0/0	4/2
	Spacenet 3	C/Ku	18/6	4/98	N/A	N/A	N/A	N/A
	Gstar 1	Ku	0/16	4/95	0/3	0/0	0/6	0/7
	Gstar 2	Ku	0/16	2/96	0/5	0/0	0/5	0/6
	Gstar 3	Ku	0/16	9/98	N/A	N/A	N/A	N/A

HUGHES	Galaxy 1	C	24/0	1993	24/0	0/0	0/0	0/0
	Galaxy 2	C	24/0	1992	6/0	1/0	6/0	0/9
	Galaxy 3	C	24/0	1994	N/A	N/A	N/A	N/A
	WESTAR 3	C	12/0	8/86	1/0	10/0	0/0	1/0
	WESTAR 4	C	24/0	2/92	14/0	3/0	6/0	1/0
	WESTAR 5	C	24/0	6/92	13/0	7/0	3/0	1/0
IBM	SBS 4	Ku	0/10	9/94	0/5	0/2	0/1	0/2
	SBS 5	Ku	0/14	1998	N/A	N/A	N/A	N/A
MCI	SBS 3	Ku	0/10	11/89	N/A	N/A	N/A	N/A
PanAmSat	PAS 1	C/Ku	18/6	1998	N/A	N/A	N/A	N/A
TOTALS					168/48	155/26	43/13	84/54

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